Towards fully biodegradable microbial fuel cells

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Introduction. In order to sustainably protect and manage the environment, a number of challenges need to be addressed, including: (i) the search for new sources of green energy; (ii) improving the efficiency of human waste treatment; and (iii) identifying methods for turning waste streams and waste materials into useful products. Furthermore, novel technologies are required to monitor the environment without impacting on the ecosystem. A technology with the potential to significantly contribute to achieving these goals is the microbial fuel cell (MFC). MFCs employ electro-active microorganisms that generate electricity as a direct by-product of the consumption (and therefore removal) of organic pollutants.

Aim. MFCs can be employed directly as sensors in remote locations or indirectly as the power source for an electronic sensor or a robotic device. To date however, materials have proved expensive and toxic. At the very least they require safe recovery from the environment once operation has ceased. The current study aims to address this by developing biodegradable MFCs that will ultimately power a biodegradable robot. The work reported herein describes the development of MFCs using natural rubber membranes and biodegradable cathodes.

Materials and methods. A biodegradable polylactic acid (PLA) frame was designed and printed using a '3D Touch' 3D printer. Natural rubber 'finger-cots' were employed as proton exchange membranes, which were placed over carbon veil anodes. Five cathode types were developed and tested: (1) conductive synthetic latex (CSL) as control; (2 & 3) non-toxic carbon paint with and without a lanolin coating; (4) egg-based cathodes; and (5) gelatin-based cathodes. Duplicate MFCs were studied in terms of power output and stability over time. In addition, the ability of individual MFCs to drive a power management system (PMS) was also investigated. The biodegradation of samples were additionally assessed using the composting facility at the Bristol Botanic Gardens.

Results. The new MFC design with PLA frame demonstrated a two-fold increase in power output over previous 'soft' natural rubber MFCs. MFCs with CSL cathodes produced the highest power (5.6 W/m^3) but were less stable between feeding. Furthermore, the natural rubber degraded in 161 days, whereas the CSL remained intact throughout composting experiments. The egg-based cathodes were comparable to the CSL controls in terms of power output (5.2 W/m^3). An egg-based MFC was then attached to a PMS through an energy harvesting board as a demonstration of real world implementation. The MFC was able to charge a capacitor to 3V, which was sufficient to energise a small windmill. The MFC was able to charge the capacitor every 12 minutes, which resulted in the windmill firing 122 times in 24 hours.

Conclusions. These results demonstrate that MFCs formed from inexpensive and environmentally-friendly materials can deliver useful power levels. The next step will be to incorporate a biodegradable anode and connecting wire. Parallel research will develop electo-active biodegradable artificial muscles for a totally biodegradable robot.

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